THE GROWTH OF SOIL ON SLOPES.*

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(Plate xiii; three Text-figures.)

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Progress in soil science has been rapid and revolutionary. Changes have taken place, not only in soil description, but in the sources from which the knowledge has been forthcoming. Formerly advances were made through geomorphology, but now they are greatest in the realms of chemistry and biology.

Soils have been divided into mature and immature soils, and for the most part soil science has confined itself to mature soils. This paper deals with the less mature soils which are characteristic of very large areas in eastern Australia.

Soil and Slope.

In any topographic unit, and irrespective of rock homogeneity, such, for example, as a major drainage area, there occurs a series of soils which bear some relation to each other; such a group we have called a *soil assemblage.* In any section of that unit, for example, a valley side, there is a sequence of soils down the slope; such a sequence we have called a *soil succession.* Such succession is characteristic of all "slopes country" and is developed step by step clearly in certain topographic situations. Theoretically the change down the slope, i.e., the outline, is the profile of the land surface in all geographical literature, and that is the English use of the word, though 'profile' is used for an outline of a transverse section of an earthwork showing the thickness at various heights. In soil science, 'soil profile' has been used for what is really 'soil cross-section', i.e., change with depth. Milne (*Nature,* Vol. 138, No. 3491) comments on this and has used the word "catena" for soil changes down the slope.

Several diagrams have been prepared to represent such a generalized soil succession for the majority of the inland slopes country of eastern Australia, and more particularly the New England, Tamworth, Mudgee, and Bathurst districts of New South Wales. The overall distance apart of these districts is 250 miles, which makes a region large enough to test the universality of the processes mentioned.

The slope and site factors of these soil groups (Text-fig. 1) are fundamental; one might call it *topographic inertia* in soil formation.

Group 1 are hilltop soils of increasing maturity.—They are always stony and shallow, and rock outcrops frequently. Bore materials show a lessened amount of stony material at first, but an increasing frequency towards the parent rock. At shallow depth there is a deepening of colour and apparent increase in clay, but always with grittiness. The deeper layers, after about two or three feet, show surprisingly fresh rock-fragments. The colours of the hilltop soils vary consider-

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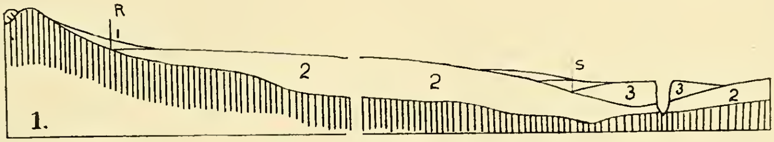
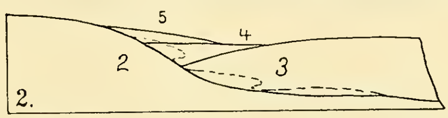
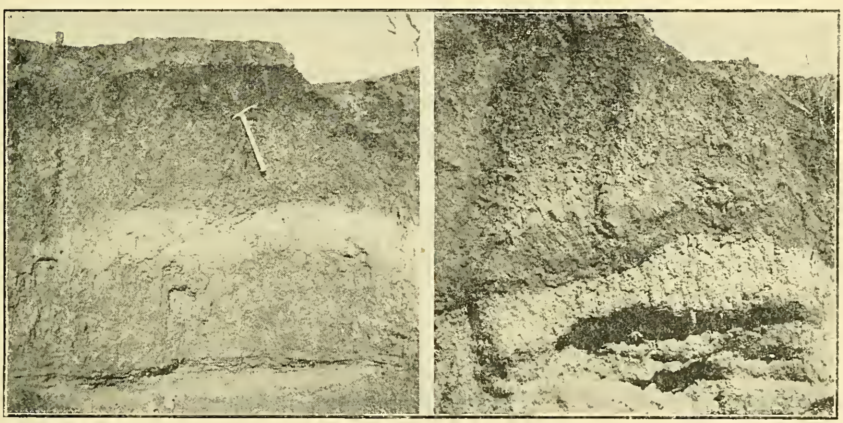
ably in apparent relation to the immediate parent rock. Shales give grey colours, slates red and brown to almost purple colours, and basalts generally chocolate to black. Since these soils are on hilltops or in exposed positions, colour-spread is common, especially if the area has been ploughed over. Profile characteristics are only slightly developed.





Text-fig. 1.—Soil succession with slope (middle horizontal distance greatly shortened). 1. Immature, stony soil; 2. Red loams; 3. River silts; 4. Black, heavy clay; 5. Light grey clay loam.

Text-fig. 2.—Junction of 2 and 3 (dotted line suggests interdigiting).



Text-fig. 3.—(right) Section represented by Profile 1. Note sharp junction between C.p. and X horizons; (left) Continuation up hill from photograph on right. Top, A2 horizon, then B horizon, C.p. (white), X (columnar), Y (undercut).

Group 2, in which middle slopes initiate aggregation and differentiation.—Over much of the Western Slopes of New South Wales and especially on the hills around Tamworth, the characteristic soils are deep, red loams. They form, for the most part, the great wheat-belt soils and some of the best pasture land. These reddish soils vary from chocolate colour, through red to brown and even to light brown. They are often very stony, invariably containing high silty zones, and can frequently be called 'sandy loams'. These "red loams" vary in depth on the upper middle slopes from three to ten feet, and on the lower slopes to greater depths. They form most frequently the convex surface, and often join the neighbouring plain or flood plain in a slight break of slope. Since these slopes are of continuous grade, and because the geological grain is often across country and the dip of the rocks is frequently at a high angle to the topographic surface, there is considerable variety of colour tone in soils, but not related to the immediate underlying rock type because of past denudation history. In general the darker colours are on the lower aspects of the slope, except where recent rainwash, accelerated by ploughing, has been active and exposed the deeper red-brown horizons, or where the line of a little runnel has accumulated the rainwash of residual light-grey soils. The profiles of these loam soils are complex, colour deepening with depth, and also clay content. At the position of what might be expected to be C horizon, there is increasing stoniness, but on boring deeper this is followed by a fresh increase in clay content, which occurs in different physical condition from the first clay zone. The change in the structural appearance is noteworthy: Profile 1 from Woolomin Parish, Portion 66 (five miles west of Tamworth), can be considered as typical:

*Profile 1.**

0″– 10″	A horizons.—Light brown sandy loam.
10″– 55″	B horizons.—Reddish, then yellowish-brown sandy loam, increase in clay and iron content, gritty, a few gravel zones.
55″– 67″	C.p. horizons.—Sandy and pebbly, hardened, whitened, very abrupt lower boundary. 53% coarse sand, 24% fine sand.
67″– 75″	X horizons.—Grey-yellow columnar sandy clay, very distinctive zone. 16% coarse sand, 22% fine sand, clay content higher than above.
75″– 87″	Y horizons.—Similar to X, less columnar, gravel increasing.
87″–107″	Z horizons.—Continuation of gravel and clay zone, much compacted, lighter in colour, and a basal zone of fresh slate pebbles, probably underlain by disintegrated shale.

The topmost layer is hardened (other than the immediate ploughed surface, which is loose) and stands out like a kerbstone. The B horizons are looser at first, then more compact, while C.p. horizon is loose again. The chief contrast is in the X horizon where the structure is distinctly columnar with sometimes spaces between the columns, especially in a gully face. The Y horizon is compacted and not columnar, while the Z horizon is often very compact and impregnated usually with lime.

This repetition in the profile is widespread and has not been described before.†

The ordinary terms for description of *depth profile* therefore are inadequate because of this "profile repetition", and we use C.p. for pseudo-C because it is best described as a false C. Further, there is probably something omitted between the C.p. horizon and the X horizon—a likelihood of contemporaneous erosion.

Topographically these middle-slope soils lie as if filling in wide undulations. Frequently the generalized surface is so smooth when ploughed that all evidence of the streams which supposedly brought the material is obliterated. The total situation suggests a wide filling in by sheet wash and under climatic conditions more intensive than at present obtain.

At one time the whole of these slopes were covered with trees, possibly some grassland, and since clearing, perfectly fresh gullies made by new assembly of rain-water and by torrential rain wash have been formed, in some cases cutting

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* The standard notation for A and B horizon differentiation has been used in these profiles, though probably a different notation could be devised for still less mature soils.

† Leeper, Nichols and Wadham, *Proc. Roy. Soc. Vict.*, Vol. xlix (N.S.), Pt. 1, p. 113. "The percentage of coarse sand passes from a maximum of 26 at the surface to a minimum of 14 at 2 ft. and rises again to a second maximum of 23 at 3 ft., below which it falls again."

to a depth of five or six feet, and having a well-formed contributory stream pattern, all having vertical wall sides. These types of gullies can be considered as giving a good cross-section of the soil. At other places somewhat similar gullies, but of an earlier phase, have been filled in and recut to rock level. These later types of gullies can be used to give an indication of the nature of the denudation repetition of the area.

The kind of accumulation that has gone on in these middle slopes and the stratification of the deposits is not found to be happening anywhere in the district at the present time. Further, any easy explanation of delta fan formation is inadequate, as the scale of flattening from the width across the slopes in proportion to the length down the slopes does not warrant such a conclusion. Again, the present lie, convexity, and middle-slope position, and their occupation as wheat and pasture lands make these red loams hazardous soil zones, that is to say, easily erodable when ploughed; this state of affairs in itself suggests instability of lie and a deposition under conditions not now obtaining.

Group 3, in which flood plains stabilize silt.—This group of soils occupies a practically flat surface bordering the middle-slope soils and forms river banks, e.g., Peel River and its tributaries. This flood-plain landform occurs on most creeks and rivers in eastern Australia, and the soils thereof are sometimes known as 'lucerne' soils.

Now these flood-plain soils are light brown river silts, dark at top, occasionally interstratified with blacker clay layers, and sometimes a thin pebble or gravel bed. Such soils vary in depth from one or two feet to 15 feet, and are being actively eroded at the present time. Although accumulation is taking place at certain points, nothing comparable to the present soils for their depth is being formed. Also some areas of these valuable dark soils are being deteriorated by down wash and even by cutting from the middle slopes. The deeper layers below the grey-black silts are often reddish, and bear some relation to the middle-slope red loams. The very lowest layers are often of a yellowish to grey-blue clay, underlain by large well-worn river pebbles. The whole profile shows several phases of recurrent deposition in quiet water, but very little of what is usually termed false bedding. Where the middle-slope soils and river-plain silts have been found in close contact, it becomes obvious that the river silts are, in general, a later deposit (Dungowan Creek Section), though sometimes interdigited.

The upper surface of these flood-plain soils slopes from the present river bank inwards towards the middle slope. The junction zone at the surface is often a depression filled with swampy, black, stiff clays (Text-figs. 1–3). These depressions are rain-wash swamp pools and may coalesce, with the help of occasional ponded-back flood river water, to become miniature creeks. The chief point is that they are filled with stiff black clays, rarely silts. Less frequently a backwater or flood distributary from a river occupies and may have formed this zone.

In the smaller and now almost dry creeks which, for the most part, are widespread throughout the area, and such as occur in the Loomberah and Bective areas (near Tamworth), the flood-plain soils are not dark alluvial, but yellow-brown sands. They have been carried from some distance upstream and deposited against the red loams. The boundary of the soil junction is often difficult to determine, but usually the farmer has planted his fence with some degree of accuracy along it, the red loam being good wheat land, and the yellow sand forming grazing and treed land. Frequently the upper parts of these creeks have been themselves filled in, usually by a very friable, dry, grey, silty loam. This latter soil probably represents savannah grey soil washed in after extensive clearings of the surrounding country.

Groups 4 and 5.—Two other important soil types, not of great extent, have developed in special topographic sites. The black, swampy clay has already been mentioned; partly overlapping it and the middle-slope red loam is a light grey rain-wash soil. These two soils (Text-fig. 2, Nos. 4 and 5) are found between Nos. 3 and 2. The grey soil often forms a "line" up a middle slope where a slight depression occurs, showing that it is superficial, and associated with recent wash and possibly with the former woodland.

The further description of these soils and profiles necessitates structural, mechanical and chemical analysis. This is being done in conjunction with a soil survey at present being carried out in the Tamworth district by W. H. Maze, Lecturer in Geography, University of Sydney.

Slope, Site, and Situation Factors in Soil Description.

From the previous description it is obvious that more than the immediate first few feet of soil is worthy of attention if even the topmost layers of the soil are to be understood, especially since those less mature soils characterize most, if not all, of eastern Australia.

Now Text-figures 1–3 and Table 1 indicate, in "slopes" country, firstly, that changes in slope set soil boundaries, secondly, that many of the chief properties of a soil type are given to it by its topographic site, and thirdly, that there is a "state of being" in soil, which is not related to the immediate underlying rock, but to the past history of the denudation of the region in which it is found.

The boundaries of soil in any succession are very important from the point of view of mapping, though the precise boundary of the major soil-type is not always observable at the surface. In Text-figure 1, for example, the points R, S, are of extraordinary interest because the changes taking place in the succession and in regional distribution can be so readily observed there. Perhaps the greatest value of these critical points lies in the way in which they lend themselves to speedy soil mapping. At once broad zones of a common "state of being" and of like continuity and behaviour are delineated almost by eye, and certainly with only a few borings.

At point R, in the Tamworth District, there is a line of change of maturity at the surface. This is brought about at first by overlapping downwash and later by gullying and sheetwash as a whole, so that Zone 1 is often being intensively eroded and point R is being moved downhill, with the placing of the lower soil regions of Zone 2 on top of that zone further down. In the past there was soil accumulation in Zone 2 which was expanding uphill. Further, at point R, there is a division of types of surface and sub-surface drainage of the soil.

At point S there are several types of change. If a slight hollow has been left at this point, then a stiff, black swamp clay has formed (soil type 4), but this is being altered at the surface by the formation of a lighter phase (soil type 5), and both may be obliterated by extreme downwash from above (soil type 2) if excessive cultivation has permitted gully erosion in the middle slope. Usually the boundary between soil types 2 and 3 is quite sharp, often with a slight break of slope (Text-fig. 2). With ploughing or excessive grazing, the silts are being overburdened with the coarser fraction of soil type 2, and the boundary is very obscure. These breaks of slope and changes of soil are obviously of great importance in soil-profile formation and in farm practice.

Slope then has this immediate significance, that there are critical points on the slope, usually breaks of slope, which have fixed the soil boundary, and this is easily recognized for mapping purposes with a minimum of profile determination.

Again, irrespective of climate or of vegetation, but having certain modifications for different climatic types, the degree of slope determines the rate of maturing of the soil, steep slopes possessing always immature soils, while more gentle slopes, if undisturbed by human activity, have soils which reach maturity. Furthermore, the nature of the slope may determine the mineral content by continued and selective downwash. On slopes of more than 10° invariably there is permanent immaturity, i.e., indefiniteness in profile subdivision, and a recognizable rock character. On slopes of less than 10° there is something of an equilibrium, less on convex, more on concave, providing there is a fair vegetation covering. On slopes of the order of 2°, especially if forming general concavity, great maturity and high clay content are common. In regions of moderate rainfall, i.e., 20 to 35 inches per annum, we have noted that the clay content increases with distance down the slope, provided, of course, the slope angle is decreasing regularly (Table 1).

TABLE 1.

Land use type	Tree covered, partly cleared.	Cleared for grazing.	Ploughed for wheat and lucerne.	Regular annual wheat crops.	Lucerne growing varying in intensity.
Tree type* ..	white box.	white box ——→ yellow box ——→ apple.			river gum.
Soil type (A horizon only)	stony grey sandy loam.	yellow-brown to red-brown sandy loam to loam.		clay loam to heavy black clay.	river silts.
Soil group and slope (as in Text-fig. 1)	steep slopes. Group 1.	middle slopes decreasing to flat. Group 2.		Concave to flat ——→ Groups 4 and 5.	Group 3
Average land value (£A) per acre (if all of one type)	about 1.	as low as 5, increasing to 20.		30 to 60 according to heaviness and uniformity.	

* White box—*Eucalyptus albens*; Yellow box—*E. melliodora*; Apple—*Angophora intermedia*; River gum—*E. camaldulensis*.

In brief, then, on exposed places, hilltops, spurs and rises, soil is becoming increasingly immature, because of physical mobility. This is a persistent tendency. On middle slopes, soils are aggregates derived from several rock types and from several vegetation formations, all of which have come from measurable and limited areas. This is still true even when there is a general homogeneity of rock type, since the geological history of eastern Australia is very varied.

Flood-plain soils have cumulative and specialized silt characteristics, high humus content, and are re-sorted so that the rock origin is unrecognizable and the clay content is at a minimum. Plain soils in continued liability to flooding are an anomaly in the sense that recurrent floods may alter the maturity or immaturity according as the flood brings down coarse or fine silt, or even soil from a neighbouring zone. Ancient flood plains, not now being flooded, will have a soil-type distribution in relation to their past flooding history and to their lie with relation to the immediate local source of the flood material and to the vegetation developed upon the flood plain. Further, the present method of profile description is not nearly adequate in view of the repetition and the "arranged" character of most of the slopes and flood-plain soils of eastern Australia. Perhaps the most significant point about slope and soil is that there is a relationship between the soils down the slope, and like slopes have many like properties.

Secondly, much can be said about the soil type from its topographic site. Invariably the red loams lie on the middle slope and have experienced erosion and subsequent accumulation, so that the unconsolidated material shows a repetition, and even the topmost layers frequently exhibit that character. The last major phase has been one of accumulation. This is shown by the fresh nature of the repeated layers and the convexity of the surface as distinct from the concavity of the underlying rock surface. Thus there is a speedier run-off in the "slopes" area than one might expect, a more complete drainage, and although much iron is present, there is rarely an iron pan, and aeration is comparatively high. Thus, in the Tamworth District, for example, the middle-slope soils, which cover the largest area, show accumulated characteristics, repetition in the profile and a "convex lie", a condition of affairs we have called "the state of being".

From the point of view of soil classification and soil behaviour, the recognition of a "state of being" seems more important than determining the underlying rock. These middle-slope soils could be stated to have a false C horizon (pseudo-C), and a mineral content recognizable only from an examination of the soil itself. Is this "state of being" of such universality that all, or nearly all, upper, middle and lower slope soils bear a precise relation to each other, and are characterized thereby, and that a new nomenclature needs to be added to soil science?

From this evidence two major ideas are derived: (1) That the rock debris and mineral content of the soil for most of the Tamworth region have been accumulated from a wide zone and from regions of considerably different geological history; and (2) that the present position of soil on any slope and the nature of that slope are very important factors in bringing soil to its present "state of being" and so contributing largely to the trends for change, both in the surface and in the profiles of the soils. For these reasons any classification has to give prominence to topographical site and slope, and the geomorphological history. After much reconnaissance and trials, we consider that any regional grouping should show (1) soil properties which obtain over all the area or large divisions of it, (2) properties of many of the topographic divisions, and (3) special properties of very limited regions. Bearing this principle of decreasing generalization in mind, the following working schedule gives (from an examination of the soil itself) an adequate basis for soil description and mapping:

1. The "state of being" of the soil (total unconsolidated layer), simple or complex history, the recognition of soil assemblage and soil succession.
2. Evidences in the topmost layers of climatic boundaries (non-lime-forming or lime-forming, degree of podsolization).
3. Boundaries of vegetation formations, or approximation thereto if land is greatly cleared.
4. Recognition of major soil-type boundaries by topographic factor (following on 1).
5. Further subdivision, by regional sampling, especially of topmost layers, on basis of colour, texture and structure (as in standard soil science practice for fully mature soils).

In addition, still further subdivisions or separate units could be made in regard to erodability, behaviour sequence, and other life history and biological properties.

Although this might appear to be much more than is wanted by a soil survey, it is necessary when one comes to inquire into the meaning of physical things and the bearing of one soil type to its neighbour. At any rate, these are the steps as they came to be recognized and their relative importance impressed upon us.

Now the Western Slopes country of New South Wales lends itself to such an examination, but over wide, extensive plains, such a soil description may be immensely more difficult to unravel. Nevertheless, as our observations show, the above categorical schedule would function for some regions more than others, but for practically all of eastern Australia, since eastern Australia is a land of plateaux and uplands, of long, gentle convex slopes and wide valley plains. Further, even in the far western plains (for example, in the Western Division of New South Wales, which is the western half of the State, and what is there would apply to western Victoria, northern South Australia, and south-western Queensland) much gentle convexity is the commonest aspect of the landscape; and it is more than an impression that the wide, extensive red soils characteristic of these western regions bear some relation to this type of slope, especially when contrasted with the equally extensive and slightly concave areas of grey soils, and the less frequent, so-called, black soil plains.

There is some virtue in the above scheme. It lends itself to progressive development with each fresh examination, for the generalized framework remains constant and gains in value as each section of any area becomes more intensively mapped, whether now or in the future.

Further, soil mapping requires to be expedited if it is to keep pace with vegetation mapping and resources mapping generally, not to speak of agriculture and road engineering progress. Soil mapping for resources purposes and for all governmental work should be up-to-date in scientific procedure, but requires only a certain scale of correctness (varying with the type of area), so that all major points and boundaries of groups are fixed and general characteristics established. Detailed soil queries in regard to a particular property will always require visitation, and also in regard to scientific problems, but these are not reasons why all soil work should be suspended until a highly trained staff of experts working a few paddocks per day can traverse Australia. Soil science has proceeded far enough now to allow fresh maps to be prepared by decades, the lesser map incorporated in the greater. Further, whole new sets of facts about climate-topography-soil, these three taken together, are required if farming is to progress, and soil mapping of this more generalized kind is both adequate for description and effective in application.

Some Interpretations.

In soil as in landform science, many of the observations can only be interpreted. There is no system of absolute proof, since much of the evidence has been removed, and only the result is observable.

Now the most significant feature in these lesser soils, shall we say, is the profile periodicity. More knowledge is needed than we can present here. In the most frequent cases the stony or sandy layer in the middle position occurs only once and we have called it a pseudo-C horizon (C.p.). It would most certainly be mistaken for a C horizon if, say, a four-inch auger were in use. Although the pseudo-C horizon is observable best in the gullies which truncate ploughed paddocks, the general smoothness of the whole surrounding filled-in middle slope indicates that the repetition must be applied to more than a very localized profile. In several cases these red middle-slope gravelly clays are used by brickworks, and so a wide selection of profiles is easily observable. In other cases road-making operations and well-digging offer similar opportunities.

Profile 2. West Tamworth Brickfields.
0 – 12″. A horizons.—Dark grey to light fawn sandy loam (stony).
12″– 30″. B horizons.—Yellow to yellow-brown gravelly loams.
30″– 32″. C.p. horizons.—This is the termination of the B horizon, which makes an abrupt junction with the X horizons below.
32″– 41″. X horizons.—Dark yellow layer, columnar, ancient plant roots, highest clay content of whole profile.
41″– 55″. Y horizons.—Red-brown sandy layer, not columnar.
55″– 67″. Z horizons.—Purple-tinted gritty layer overlying shale.

Profile 3. Bective Parish. Portion 100.
0 – 12″. A and B horizons.—Fine light grey sandy loam.
12″– 30″. C.p. horizons.—Soil with angular pebbles.
30″– 36″. X horizons.—Clay and less pebbles, terminating abruptly.
36″– 47″. Y horizons.—Deposition zone of iron, clay and lime, hardened, also ending in a sharp break.
47″– 65″. Z horizons.—Fine dark brown sandy clay chiefly, no stony material, columnar.

Profile 4. Denistone Station, near Werris Creek.
0 – 36″. A and B horizons.—Typical black soil, high clay content.
36″– 60″. C.p. horizons.—Light brown sandy loam ending abruptly in fine gravel.
60″– 84″. X horizons.—Dark brown soil, columnar, high clay content, lime pipes very well developed, not terminating in decomposed rock since underlain by several gravel and pebble beds.

Profile 5. Ploughed area seven miles from Somerton on Gunnedah Road.
0 – 6″. A horizons.—Fawn sandy loam.
6″– 54″. B horizons.—Similar to above, darker, slightly columnar.
54″– 66″. Light brown sandy soil.
66″– 72″. Soil and pebbles.
72″–108″. C.p. horizons.—Brown soil ending in a sharp, but undulating line of fine sand.
108″–156″. X horizons.—Dark columnar, grey-brown soils of river silt type.
156″–168″. Y horizons.—Silt deposit, conspicuous lime pipe deposition, and large pebbles at the base.
Z horizons.—Very compacted layer of disintegrated rock, cemented with spongy limestone, has the appearance of an artificially cemented rubble.

Profile 6. Mudgee.
0 – 12″. A and B horizons.—Light brown sandy loam.
12″– 24″. C.p. horizons.—As above with increase in light gravel and pebbles.
24″– 42″. X horizons.—Columnar structure, increase in red iron.
42″– 60″. Y horizons.—As in X, absence of columnar structure, increase in gravel.

Profile 7. Bathurst.
0 – 34″. Brown silty loam, lucerne.
34″– 37″. Zone of quartz pebbles.
37″– 67″. Brown silt.

67″– 77″. Black silt, very noticeable at a distance.
77″– 97″. Brown silt as above, but shaded into by black silt.
97″–121″. Slaty pebbles and silt.
121″–133″. Large pebbles in layers.

The above profiles (2–7), and our observations over the 2,000 square miles of the Tamworth district, the Mudgee, Bathurst, New England, Lake George, and Broken Hill areas, and the region from Adelaide to Tapley's Hill, South Australia, indicated wide universality of the pseudo-C horizon (C.p.). In some cases charred wood remains are present, which indicate that the several feet of soil overlying is of comparatively recent deposition, though before the time of the present tree growth and well before cultivation. Where much accumulation has gone on in the middle slope of recent date, due to ruthless clearing of the upper slope, or for some reason where a new cycle of erosion has commenced, as in the Dungowan Creek (Tamworth) district, the profile shows a very great degree of immaturity and an irregularly mixed character.

The stony or gravelly nature of the pseudo-C horizon indicates a change in the kind and rate of deposition. The layer below the pseudo-C horizon is a stiff clay and may represent an old B, or even an A, horizon, now overlain by several feet of soil which has been long enough in position to have its own A, B, horizons.

Why this change in deposition should have taken place is harder to explain, yet it must have taken place before European occupation of Australia, which in many of the areas under discussion has only become intensive in the present century.

The pseudo-C horizon, the soil-type distribution patterns, their depth in certain areas, and the absence of depth where depth might be expected, and the inability of the present forces to form such soils to-day, suggest past conditions of slope and climate, perhaps of elevation, different from those of to-day. There is recent acceleration of erosion (a new cycle some would call it), apart from that additional erosion brought about by man-made factors of clearing, cultivation, etc. This is confirmed by a statistical examination of erosion on upper, middle, and lower slopes, where many fresh evidences are apparent, by erosion on both banks simultaneously and on the beds of creeks, and by the advance of the hill slope against the flood plain at all re-entrants. Further, there is a general convexity of the aspect of the elements of landscape. This, of course, in addition to the long period of erosion to form the general drainage pattern already mentioned.

It is fair speculation that an examination of the soil profile and the classification of soils as above may give information which will help in the solution of the immediate past climate of Australia and confirm other meagre evidence that Pleistocene times were more pluvial than the present. The periodicity in the profiles and the widespread distribution of deep middle-slope soils, and the extent of the valley floors indicate a greater period of deposition over the area than obtains at present.

The sequence of events from the deposition evidence suggests a development of the landscape over so long a period of time that the stream pattern bears little relation to the geological grain of the country, for example, streams traverse anticlines and synclines indiscriminately (Currabubula Creek, the Peel tributaries). During this period a soil surface was developed. At a very much more recent date, and somewhat cataclysmic in its incidence, increased denudation took place which involved a smoothing of the landscape, greatly increasing deposition eventually on the middle slopes. There was greater flow in the rivers and, as this flow decreased, wide silt plains were built up. This increased deposition throughout the slopes country was not a single event but a period of events which slowed down. Yet more recently, and accelerated by land usage of to-day, denudation has become revived and is removing the previous widely-spread deposition. It is possible from this evidence that the land was more rugged and at greater elevation than at present, or that, in view of the comparative flatness of the New England area, and other areas in eastern Australia at a high elevation, there was in recent geological times a general uplift of considerable amount, and the effect of this uplift has made itself felt most in slopes country.*

In early determinations of soil, rock character was given pride of place, and as long as the A and B horizons can be shown to be directly related to a C horizon which is being formed from disintegrating rock *in situ*, then the rock-type name will indicate the soil-type name, and in very immature soils no better classification can be suggested. From the previous discussion, however, it is obvious that the disintegrated rock spreads from one rock type to the next, and in the case of the middle-slope soils, as already stated, the soil type bears little relation to the underlying rock type, and the rocky character of most silt soils cannot be given an immediate origin.

One tendency on slopes is towards uniformity of soil type, since forces making for erosion and transfer are obliterating the distinctions outlined above (Table 1); the grey hilltops merge into the red loams and both encroach on the river silts, which in themselves are being eroded away. This is so not only in the realm of soil but in land valuation. Loams (soil type 2) are valuable wheat soils, while river silts are still more valuable lucerne soils. If erosion continues there will be a general uniformity of soil type and a reduction in value throughout to the lower level (Table 1).

In the Western Slopes of New South Wales, with the initiation of a fresh cycle of activity the natural tendency would appear to be towards increasing immaturity, which is the real issue in soil erosion as distinct from the part played by farm husbandry.

In Text-figure 1, soil types 4 and 5 are a light covering (No. 4 may be three or four feet deep) of more recent soils, and are a continuation of that process of smoothing out the topography which was begun many decades ago, though the greater processes of erosion are going on alongside. This is where the complexity lies, namely, the relative value to be attached to contradictory processes going on simultaneously.

There is still another aspect. In the International Soil Classification, colour is given a high place as a soil indicator, and to a great extent soils are classified on their colours. It has been shown already that the soils in the Tamworth District take their colour to a great extent from their topographic position, the general mass of soils being dark flood soils and red loams, though in the neighbourhood of rock outcrops the rock type may be said to determine the soil colour. For example, shales give grey soils, basalts dark red-brown to black, slates red, granites yellow to brown soils. Where the land has been only recently ploughed there is a thin remnant of colour, probably derived from the nature of the primeval vegetation. Further, the chocolate, red and brown colours are very difficult to distinguish because of frequent ploughing, frequent burning of stubble and especially because lateral soil wash spreads the material from the topmost zone and also frequently exposes the deeper reds and yellows of the B horizon.

* W. H. Maze is testing this by making a Slope Variation Map of part of the Western Slopes of New South Wales.

It is this very variety of colour-change which gives many clues to soil behaviour, so that to average the colour for a single paddock destroys the very evidence one requires. The usual method of colour determination as an indicator of soil type when applied to moderately mature soils would appear to be rather ineffectual.

As mentioned at the beginning of this paper, soils must be described from their inherent qualities, and with world-wide possibilities of correlation, yet climate-topography-soil are inseparable, and if soil is to be considered one thing, and not a multitude of different things, they dare not be divorced. Furthermore, climate-topography-soil conjointly are the basis of regional policies of land usage, and perhaps even of farm husbandry—but that argument must await another occasion.

In summary, then, soil can be considered as the end point of landscape development and the idea of growth, separate and contemporaneous, used as a basis of classification. Further, soil types have persistent characteristics due to topographic inertia. Thus do major soil groups become recognizable in the field. In the topographically less stable soils physical change is the most important feature, but in the more stable the chief changes are chemical. These changes, too, vary in given sequences with soil depth, according to the original and accumulated mineral content, the vegetation formation, and the present climatic régime. Thus depth profile gives a further basis for group subdivision, though these profile changes themselves promote soil uniformity over any given climatic region where soil accretion is nil.

Again, if the soil growth be periodic in well-defined stages—a feature observable best in the less mature soils—changes in the type and rate of denudation are indicated. This periodicity may make possible the measurement of changes in tectonic forces and/or long-range climatic succession.

In eastern Australia soils are still forming. In some localities this is recognizable by a planing-off of a convex and still unstable slope and the filling-in of an equally unstable concavity. This smoothing-out of the topography is not likely to be completed since statistical counts of these apparently contradictory processes, in conjunction with hilltop erosion and changes in river behaviour, favour a widespread rejuvenation of the whole denudation processes.

EXPLANATION OF PLATE XIII.

The four colour photographs in Plate xiii in conjunction with Text-figure 3 are a pictorial conspectus of the types of country in the Western Slopes of New South Wales. The Dufay Colour Film used has over-emphasized the blue tones, especially in the reflected colour of the river water (Fig. 4); otherwise the colours are typical.

Fig. 1.—Soil cross-section as in Text-figure 3. Shows especially columnar clay zone undercut in middle position and the pseudo-C horizon above it.

Fig. 2.—Typical agricultural occupation on soil group 2. Foreground shows grazing land fully cleared; a few dead trees still stand. Middle distance shows lower convex slope with typical tree types remaining from original open woodland, and young wheat (green). The far middle distance shows a typical low, stony rise, with sufficient soil on it for ploughing, on which high wheat yields are possible in years of good rainfall.

Fig. 3.—A small section of country shown in Fig. 2, representing a convex slope in young wheat, but eroded by gully formation. The A and B horizons in the soil are shown by light and dark tints in the red. This was taken following a good rainy season and the floor of the gully is occupied by weeds. Typical grazing and treed slope in background.

Fig. 4.—This shows the typical lucerne flat bordering the Cockburn River and also the other rivers of the district. The flat nature of the surface is indicated and the depth of silt; the vertical cross-section is typical and is due to undermining and collapse. The surface covering is lucerne. At this point a river flood had carried away much valuable lucerne area, as indicated by the fresh cross-section and the lucerne growing right up to the edge.

For geographical accuracy Figures 1 and 4 should be reversed. They have been processed from the wrong side of the positive colour film.